THE COMPLETE X-BAND NAVIGATIONAL RADAR SET

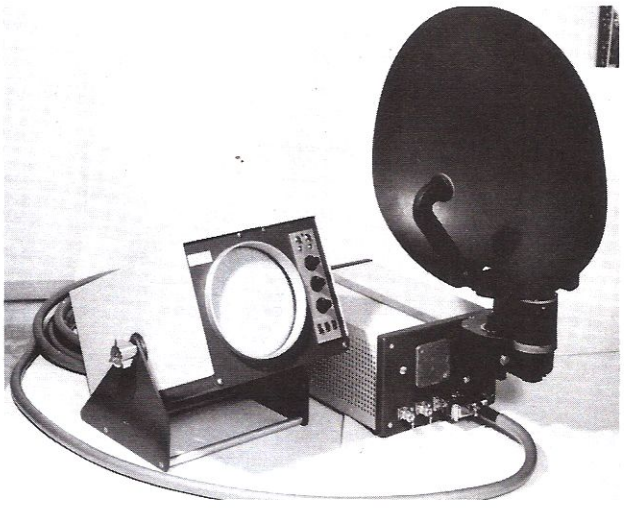
I. INTRODUCTION

A complete solid state circuitry, X-band, navigational radar set, having 10 KW pulse power and a 25-mile maximum range with a resolution of 400 feet, was designed and constructed at Fairchild Semiconductor. The purpose of this project was to demonstrate that a practical set can be made using only silicon planar transistors and with SCR switches in the modulator. Certain circuit simplifications improved reliability markedly and made field adjustments of range markers and sweep circuits unnecessary.

The complete experimental set is shown in Fig. 1. There are two units, the Transmitter, which is 6" x 9" x 13" (not including antenna), and the Indicator, which is 9-1/2" x 14" x 8". The design is versatile allowing either fixed or portable use. The power supply is described for 28 V d-c inputs but may easily be adapted to 12 V d-c or 115 V a-c. The set has such multifold possible uses as in airport surveillance, maritime navigation, airborne navigation, and portable military installations.

High-performance silicon transistors are beginning to be employed in many equipments which have conventionally used vacuum tubes. Before high-voltage silicon planar video transistors, and silicon planar transistors with gain-bandwidth products in the order of 900 mc, were available, receivers suitable for radar that would operate in military environments could not be built.

As design of high-frequency and video transistor circuits is abstruse and departs in many respects from vacuum-tube practice, the design pro-



THE COMPLETE X-BAND ALL SOLID STATE DEVICE NAVIGATIONAL RADAR SET

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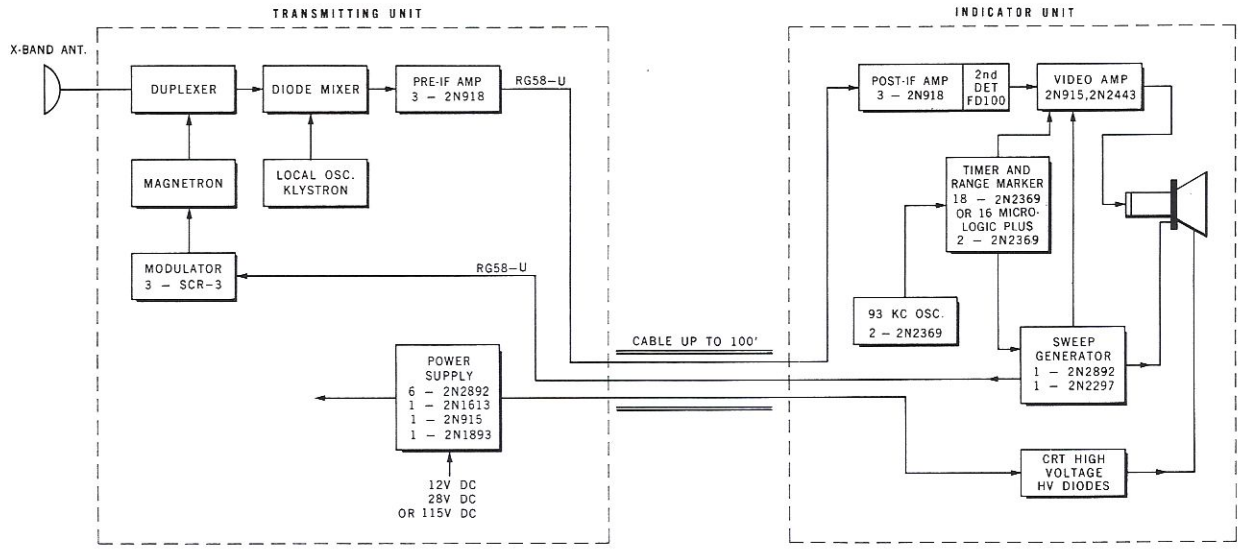

FIG. 2. Block diagram of complete radar.

cedures for the radar are fully covered in a series of application notes written by Samuel A. Schwartz. The complete series is listed below:

APP-76	"A Transistor Video Amplifier for Radar Display"
APP-77	"Transistor Range Marker and Sweep Generator for Radar Display"
APP-78	"I-F Amplifier for a Radar Receiver"
APP-79	"Silicon-Controlled Rectifier Pulse Modulator for a Radar Transmitter"
APP-80	"Transistor Power Supply for a Portable Radar"
APP-81	"The Complete X-band Navigational Radar Set"

A block diagram of the complete radar covered in these notes is shown in Fig. 2.

II. CONSTRUCTION

The transistor sections of the experimental radar use straightforward printed-board wiring. Large, heavy components, such as power transformers, pulse lines, etc., are mounted on the aluminum frame or panels. "L" shaped covers are easily removed to view the interior.

Indicator unit

The indicator unit incorporates a 7" CRT with sweep circuitry for a PPI presentation, timing and range circuits, CRT high-voltage supply, and part of the receiver. The left side of the indicator unit is shown in Fig. 3. The post i-f amplifier and the video stage are seen mounted vertically on the center panel. The right side of the indicator unit is shown in Fig. 4. The large printed board contains the crystal oscillator, frequency dividers, and sweep generator. The 2N2893 sweep output transistor can be seen at the top center of the board, and the 2N2297 sweep generator driver (identified by the heat sink around the can) is just to its right. On the bottom right, behind the center panel, can be seen the pot-locks for the 5- and 25-mile range amplitude adjustments. Above them is the cubical cover housing the sweep-range inductors, and at the rear is the yoke drive motor with heat sink.

Transmitter unit

The left side of the transmitter unit is shown in Fig. 5 and the right side in Fig. 6. The printed board in Fig. 5 is the power supply board, which contains all of the rectifier-filters and the voltage-regulator circuits. The cans seen to the left rear

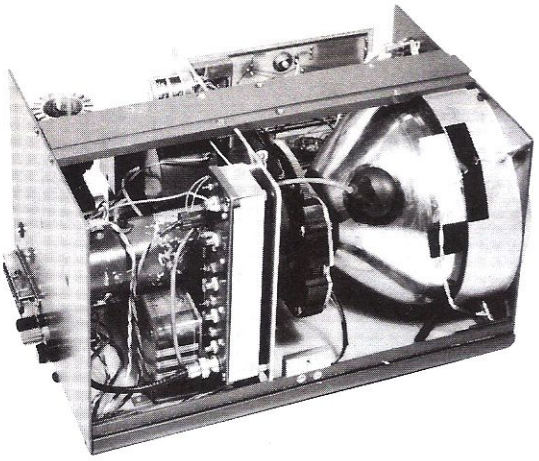

FIG. 3. Left side of indicator unit.

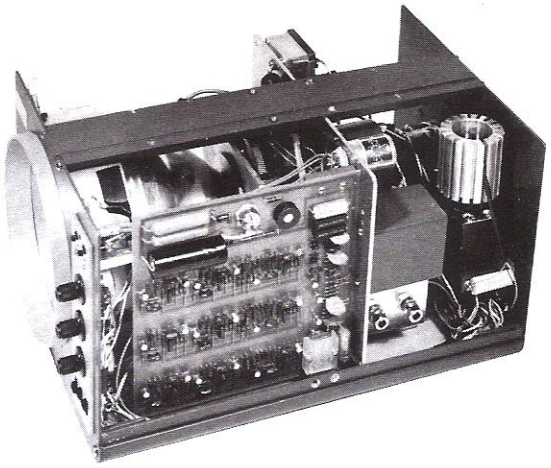

FIG. 4. Right side of indicator unit.

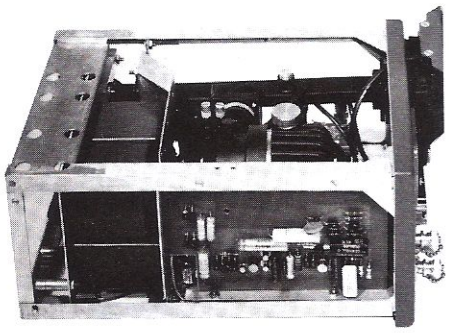

FIG. 5. Left side of transmitter unit.

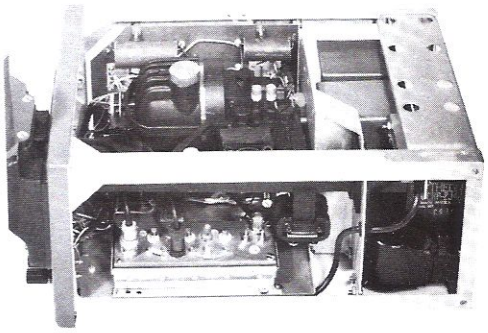

FIG. 6. Right side of transmitter unit.

encase the modulator components. The right side view (Fig. 6) reveals the shielded rectangular box that houses the i-f preamplifier.

III. SILICON PLANAR DEVICES

Except for some of the diodes and microwave tubes that are not available in the Fairchild product line, the entire circuitry of this radar set uses high-performance Fairchild silicon planar devices designed to meet or exceed MIL-750 standards.

Particularly improved were the video and i-f amplifiers. The desired bandshaping was easily provided because of the low capacitance of the silicon planar devices at low impedance levels. A voltage gain of 40 is provided in the video amplifier with only two transistors giving a 60 V peak-to-peak output and a bandwidth of 80 mc.

The i-f amplifier, which uses 2N918's (900 mc f_t transistors), gives a voltage gain of 120 db. Only six stagger-tuned stages are needed to raise a 1 μV

TABLE I
SILICON PLANAR TRANSISTOR COMPLEMENT AND OTHER DEVICES

SECTION OF RADAR	TYPE NUMBER	Total No.	STAGE/S	DESCRIPTION OF TRANSISTOR	CHARACTERISTICS
VIDEO AMPLIFIER APP-76	2N915	1	Input	Uhf amplifier with high breakdown voltage	f_t (typ) = 400 mc @ I_C = 10 mA V_{CEO} = 50 V
	2N2443	1	Output	High-voltage video amplifier	f_t (typ.) = 80 mc at I_C = 50 mA; V_{CEO} = 100 V
RANGE MARKER & SWEEP GENERATOR APP-77	2N2369	2	Crystal Osc.	650-mc amplifier and switch	f_t (typ.) = 650 mc at I_C = 10 mA
		1	Marker Amplifier		
		16	Divider Flip-flops		
		2	Range Set Flip-flop		
	2N2297	1	Sweep Gen. Driver	High-current, medium-power, 90-mc epi. amplifier and switch.	P_D = 5 W; f_t (typ.) = 90 mc at I_C = 50 mA; V_{CEO} = 35 V
	2N2893	1	Sweep Output	High-voltage, high-power epi. amplifier and switch.	P_D = 30 W; V_{CEO} = 80 V; f_t = 50 mc at I_C = 200 mA; I_{CEX} = 100 nA max @ V_{CE} = 60 V
	Micrologic Elements Nos. 905, 906	16	Frequency Dividers	905 — half shift register with inverter	———
				906 — half shift register without inverter	———
I-F AMPLIFIER APP-78	2N918	6	All Stages	UHF oscillator and amplifier	f_t = 900 mc at I_C = 4 mA
	FD 100		Second Detector	Ultra fast planar diode	———
MODULATOR APP-79	SCR-3	3	Modulator Switch	High-speed, high-voltage silicon-controlled rectifier	V_{BO} = 400 V; V_f = 3V @ I_A =10A To-5 pkg.; I_s at rated V_{BO} = 25 nA.
POWER SUPPLY APP-80	2N2892	2	Synch. Power Osc.	High-voltage, high-power epi. amplifier and switch	P_D = 30 W; V_{CEO} = 80 V; f_T = 46 mc at I_C = 200 mA
		2	Power Amplifier		
		2	Series Volt. Regs.		
	2N1893	1	+300 V Volt. Reg. Control	High-voltage amplifier	V_{CER} = 100 V
	2N915	1	12 V Volt. Reg. Error Amplifier	High-frequency amplifier & oscillator	f_t (typ.) = 400 mc at I_C = 10 mA; V_{CEO} = 50 V
	2N1613	1	12 V Volt. Reg. Control	General-purpose amplifier & switch	h_{fe} = 100 mc at I_C = 50 mA
	2N2297	2	Sync. Inverter & Amplifier	High-current, medium-power, epi. amplifier & switch	P_D = 5 W; f_t (typ.) = 90 mc at I_C = 50 mA; V_{CEO} = 35 V

input to 1 V output with a 10-mc bandwidth at 60 mc center frequency.

Particularly noteworthy is the use of a sweep oscillator with timing and marker circuits which functions virtually as a clock for the complete system. Since the main power supply is also triggered from the sweep oscillator, switching transients that could cause interference on the PPI occur outside the sweep period. Type 2N2369 high-speed planar epitaxial transistors are used in the oscillator and frequency-dividing flip-flops. An alternate circuit uses a series of integrated storage elements, Micrologic Parts 905 and 906, which eliminate most of the wiring and passive components.

Table I lists the complete transistor complement and includes a brief description for identification purposes.

IV. CONCLUSION

The advantages of solid-state radar are emphasized by comparing the Fairchild Semiconductor experimental radar with the all-vacuum-tube APS-10 airborne radar manufactured in the latter part of World War II, both of which have similar capability (10 KW peak power and 135 db receiver sensitivity). *

The APS-10 weighs about 124 pounds and the solid-state radar 40. The power required by the solid-state radar is considerably less: only 70 W input compared with 420 W required by the APS-10.

The design, construction and performance of this experimental radar show that such equipment is practical and reliable; in addition it offers the many advantages concomitant with solid-state circuitry, such as long life, small size, light weight, etc. There seems little doubt, therefore, that maritime as well as other types of radar will eventually be composed almost entirely of solid-state circuits.

*Currently available marine radars of similar performance characteristics have very nearly the same power and weight specifications as the APS-10.